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SOLAR WIND INTERACTION WITH COMET BENNETT (1969i)

by

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Abstract

This paper examines the relations between the solar-wind and Comet Bennett during the period March 23 to April 5, 1970. A large kink was observed in the ion tail of the comet on April 4, but no solar-wind stream was observed in the ecliptic plane which could have caused the kink. Thus, either there was no correlation between the solar wind at the earth and and that at Comet Bennett (which was 40° above the ecliptic) or the kink was caused by something other than a high-speed stream. The fine structure visible in photographs of the kink favors the second of these alternatives. It is shown that a shock probably passed through Comet Bennett on March 31, but no effect was seen in photographs of the comet. A stream preceded by another shock and a large abrupt change in momentum flux might have intercepted the comet between March 24 and March 28, but again no effect was seen in photographs of the Comet. In view of these results, one must seriously consider the possibility that a large, abrupt change in momentum flux of the solar-wind is neither necessary nor sufficient to cause a large kink in a comet tail.

Introduction

Several observers have reported large perturbations in Type I comet tails (Barnard, 1909; Biermann, 1951, Lüst, 1961, 1962; Biermann and Lüst 1963, 1966; Miller, 1969; Jockers and Lust, 1972) and have attempted to relate them to solar or geomagnetic activity. It is generally presumed that the perturbations are due to disturbed conditions in the solar wind (i.e., high speed streams or shocks) and that these conditions are associated with solar activity or geomagnetic activity. However, no unambiguous relation between in situ solar wind measurements and solar activity has been demonstrated. In fact, it is still not even known whther fast solar-wind streams come from active regions or quite regions on the sun. Similarly, there is only a weak correlation between solar-wind conditions and geomagnetic activity as measured by the ΣKp index (Snyder et al., 1963; Ogilvie et al., 1968). Thus, to obtain definitive results concerning the short-term variations in comet tails, it is necessary to relate comet observations directly to solar-wind measurements.

The passage of Comet Bennett (1969i, 1970II) at a time when the solar wind was being monitored by satellites provided an opportunity to study the solar wind-comet interaction directly. In particular, a high speed stream and a shock were observed at spacecraft near earth on March 27, another shock probably passed the earth on April 1, and a large kink in the Type I tail of the comet was photographed on April 4. The purpose of this paper is to study the effects of the shocks and stream on the comet tail, and to investigate the cause of the kink.

If the spacecraft were close to the comet and in the same orbit, it would be trivial to relate the solar-wind observations to those of the comet. However, the available solar-wind data were obtained from spacecraft which were several tenths of an AU away from the comet. Thus, a model is needed to relate the two types of observations. Additional complications arise because the solar wind data were neither continuous nor complete.

The comet observations are described in Section II. The solar-wind observations at 1 AU in the period March 23, 1970 to April 5, 1970 are presented in Section III. Their extrapolation to the comet and the interaction between the solar wind and the comet are then discussed in Section IV.

II. Comet Observations

Comet Bennett was discovered on December 28, 1969, by J. C. Bennett as an 8th magnitude object. Near perihelion it was easily visible to the naked eye. Because of its extraordinary brightness it was observed at many locations until the summer of 1970.

The orbital parameters of Comet Bennett (Marsden, 1972) are as follows:

$$
\begin{aligned}
e &= 0.996 \\
q &= 0.54 \text{ AU} \\
\omega &= 354.2^\circ \\
\Omega &= 224.0^\circ \\
i &= 90.05^\circ
\end{aligned}
$$

Perihelion was at T = March 20.05 ET, 1970. Note that the orbital plane was perpendicular to the ecliptic and that perihelion was at 0.54 AU. Figure 1a shows a plot of the orbit in the orbital plane. Figure 1b shows the projection in the ecliptic plane (it is on the $\hat{\underset{\sim}{Y}}$-axis) together with positions of the earth and the spacecraft Pioneer 8. The Y axis extends from the sun to the ascending node, $\hat{\underset{\sim}{X}}$ is perpendicular to $\hat{\underset{\sim}{Y}}$ and in the ecliptic plane, and $\hat{\underset{\sim}{Z}}$ is normal to the ecliptic. The true anomaly, V, was computed from Hirsts' Table for Parabolic Orbits' (Hirst, 1967) using $M = (t-T)q^{-3/2}$, and the distance from the sun, r, was computed from the equation $r = q \sec^2(V/2)$.

On April 4, 1970, a large kink was seen in the Type I (ion) tail of Comet Bennett. This is illustrated in Figure 2 which is a reproduction of a photograph taken at Hamburg Observatory at 0259 UT. At the time of observation, the distance of the kink from the nucleus amounted to about 1.8×10^6 km. The length of the visible tail was limited by the plate border to about 8×10^6 km. The heliocentric and geocentric distances of the comet were $r = 0.64$ AU and $\Delta = 0.76$ AU, respectively.

As is clearly noticable on this photograph, the kink can only be seen in one part of the ion tail. The other part is not affected at all by its appearance; it consists of a bundle of several slightly diverging sharp streamers superimposed onto the uniform dust or Type II tail. The rays in this second part of the ion tail are undisturbed except for a small displacement of some rays near the kink. The angle between these two parts is about 25° (Wurm and Mammano, 1972). The disturbed ion tail forms an angle of about -5° with the prolonged radius vector from the sun to the nucleus of the comet, that is its tail axis precedes the radius vector in the direction of the orbital motion of the comet. The undisturbed bundle lags the prolonged radius vector in the direction of motion by about $+20^\circ$.

The same feature was present on April 4 at 0128 UT; at 0252, 0256 and 0305 UT; and at 0356 UT; according to photographs from Abastumani, Asiago and Meudon Observatories, respectively. It could not be detected at 0355 UT on April 3, according to a photograph from the Bonn Observatory. Thus the kink developed between 0355 UT on April 3 and 0128 UT on April 4. We are interested in investigating the relation between this kink and solar-wind conditions.

Visual observations of Comet Bennett (Beyer, 1972; Bortle, 1972) revealed only an essentially continuous decrease of the total magnitude of the comet for the period in question. Bortle's observations moreover, indicate no unusual outbursts or activity other than the fountain-like activity in the inner part of the coma which had been going on since early March (Bortle, 1972).

III. Solar-Wind Observations.

Several spacecraft with plasma detectors were in orbit during March and April 1970, including Pioneers 6, 7 and 8 which were orbiting the sun at various longitudes near 1 AU; OGO-5, VELA's 5 and 6, Explorer 41 and HEOS-1 which were orbiting the earth; and Explorer 35 in orbit around the moon. In addition, there was a plasma analyzer in the ALSEP package which was placed on the surface of the moon by the astronauts on Apollo 12. Among the Pioneers, only Pioneer 8 was monitoring the solar wind reasonably close to the comet and the earth (the data are, however, rather sketchy, and only a few estimates of speed could be obtained). Explorer 41 was in the magnetosheath during the interval of interest. The plasma detector on Explorer 35 was not operating. Our discussion is based primarily on the solar wind data from OGO-5, ALSEP and Vela 5 for the period March 31-April 5, 1970. Discussions of the corresponding plasma analyzers may be found in Neugebauer (1970, 1971), Snyder et al. (1970) and Bame et al. (1970), respectively.

Most of the energy in the solar wind is in the streaming motion. The interaction between the solar wind and an obstacle depends strongly on the momentum flux nV^2 where n is the density and V is the solar-wind speed. Thus, we shall limit our discussion to the variation of V and nV^2. Figure 3 shows V and nV^2 as a function of time as seen near the earth between March 23 and April 5.

April 2 to 4. On April 4, the speed measured by OGO-5 was 440 km/sec. On March 30 the speeds were similar (425 km/sec). Very few OGO measurements are available between these dates. On March 31 the ALSEP solar-wind spectrometer measured high speeds (550-620 km/sec); then the sun set on the instrument. For most of March 31 and April 1, the speed decreased approximately linearly from 620 km/sec to 450 km/sec. The data for the latter part of March 31 and for April 1 are from the electrostatic analyzer on Vela 5. The combined observations show that a high-speed stream passed the earth between March 31 and April 1. This caused a geomagnetic disturbance, the largest Kp being 6 during the middle of March 31, and was followed by an ssc at 2153 UT on April 1. Although the data are sketchy, Figure 3 shows that there was an increase in speed on March 31, which was almost certainly caused by an increase in density and momentum flux caused by compression ahead of the stream. Very few data are available for April 2 and 3.

However, there are three indications that no fast stream was present on these days:

1. OGO-5 was in the solar wind for a few hours, but accurate measurements of the solar wind fluid parameters could not be obtained because the instrument suffered from "photodip" troubles which occur only when the solar-wind speed is in the range 320 to 405 km/sec (Neugebauer et al., 1972). Thus the photodip problem itself indicates the absence of a fast stream.
2. Another reason for the paucity of solar-wind data from OGO on April 2 and 3 is that the bow shock was unusually far from the earth at this time, beyond the radius of OGO-5. In particular, on the orbit under consideration, OGO-5 was beyond 10^5 km from the earth between 0100 UT

on April 1 and 1400 UT on April 2, yet only a few hours were spent in the solar wind. But on the following orbit OGO-5 was in the solar wind most of the time that it was beyond 10^5 km (from 1500 UT on April 3 to 0500 UT on April 5). Thus the bow shock was farther from the earth during the first orbit than the second. This implies that nV^2 for the solar wind on April 1-2 was less than on April 3-5 (Fairfield, 1971; Spreiter and Alksne, 1969). Since the solar wind flux, nV, generally decreases with V (Burlaga and Ogilvie, 1970; Wolfe, 1972) it follows that the solar-wind speed on April 1-2 was probably not greater than the speed on April 3-4, which was determined to be $\approx$400 km/sec.

3. The Kp indices for April 2 and 3 were relatively low ($Kp \leq 2$ on April 2; $Kp \leq 4$ on April 3) suggesting speeds $\leq$ 400 km/sec (Snyder et al.(1963). The uncertainties in obtaining V in this way are, however, rather large.

We conclude that there was probably no fast stream at the earth on April 2 and 3. In the absence of measurements for this interval and in view of the above discussion, we approximate the speeds in Figure 3 by a straight line connecting the last point on April 1(which is from OGO-5) with the first point on April 4. There was no appreciable change in n and V on April 4.

Probable Shock on April 1. A geomagnetic impulse at 2153 UT on April 1 was reported by 32 magnetic observatories around the world (Solar Geophysical Data). Twenty-two observatories classified the event as a storm sudden commencement (ssc) and only seven classified it as a sudden impulse (si). (For definitions of ssc and si, see the review by Burlaga, 1972a). In accordance with the results of Burlaga and Ogilvie (1970) and Chao and Lepping (1972), which show that ssc's are generally caused by shocks, we infer that the impulse on April 1 probably signaled the arrival of an interplanetary shock. Unfortunately, no direct interplanetary measurements of the shock are available. Measurements from Vela and OGO made an hour after the ssc (Figure 3a) show that the wind speed was not increasing behind the shock. Thus, the shock was evidently not "driven" by a fast stream (Parker, 1963; Burlaga, 1972b; Hundhausen, 1972).

March 27 Stream and Shock. A stream passed the earth on March 27 (see Figure 3a). The maximum speed was not high (484 km/sec), but the speed gradient was rather large, the speed changing by 222 km/sec in 7 hours. This stream is notable because it was accompanied by a very large momentum flux and because it occurred when the comet was relatively close to the ecliptic ($\approx 0^{\circ}$ to $\approx 25^{\circ}$) although still far from the earth (≈ 0.7 AU). This stream was preceded by an ssc at 0657 UT on March 27, suggesting the arrival of a shock. At the time of the ssc a discontinuity was observed by spacecraft in the solar wind near the earth. The density and speed increased across the discontinuity, consistent with the passage of a shock. The spacecraft observations are not sufficiently complete to allow computation of the shock orientation and speed from the Rankine-Hugoniot equations. However, if it is assumed that the shock was moving nearly radially away from the sun as is usually the case (Burlaga, 1972; Hundhausen, 1972; Chao and Lepping, 1972), then the speed can be calculated from the fact that the discontinuity moved from OGO-5 at 0659 UT to ALSEP, which was 43 R_E downstream, 12 min later, at 0711 UT (Neugebauer et al., 1972).

This gives for the shock speed, $V_s \approx 380$ km/sec, or 120 km/sec relative to the solar wind, which is similar to other reported shock speeds (Hundhausen, 1972; Chao and Lepping, 1972). The momentum flux increased appreciably just behind the shock as one expects as a result of the increase in density across a shock. The momentum flux continued to increase for a few hours behind the shock.

IV. Relation Between Solar Wind and Comet Observations

The kink on April 4, 1970. Let us consider the cause of the kink in the tail of Comet Bennett, shown on Figure 2. Recall that the earth and the comet were widely separated at the time of interest, as indicated in Figures 2 and 4. Thus, a model is needed to relate observations of the solar wind at the earth to the solar-wind conditions at the comet.

Two extreme models are possible. One assumes a spherically symmetric, time-dependent solar wind, while the other assumes an asymmetric wind which is time independent in a frame rotating with the sun. The latter implies that the streams are steady, form a spiral pattern, and corotate with the sun. The actual situation varies between these two extremes.

Gosling and Bame (1972) found that generally streams tend to corotate, although they do change appreciably on a scale of several days. Since the corotation time between the earth and Comet Bennett was less than two days, it is reasonable to adopt the model in which the solar wind was corotating. Since Comet Bennett was well out of the ecliptic at the time of interest and since the solar wind moves nearly radially away from the sun, the plasma that hit the comet came from a higher solar latitude, λ, than that which passed the earth; thus, an additional assumption is necessary concerning the latitude dependence of the solar-wind speed. We shall make the simplest assumption, viz, $V(\lambda) =$ constant. Finally, there is a problem because the rotation period of the sun, and thus perhaps the rotation period of the solar wind, varies with latitude (Goldberg, 1963). We shall first assume that the rotation period is approximately a constant equal to 27.5 days; the effect of a changing period will be considered later.

Given the above assumptions, one can transform the solar-wind conditions measured at earth to those at the comet as follows. Consider an element of plasma which leaves point A in Figure 4 at time t_A, moves radially away from the sun, and meets the comet at time t_B. Since $V(\lambda)=$ constant, a similar element of plasma leaves A' at t_A and at time t_B arrives at point B' in the ecliptic plane, which is a distance $R_B(t)$ from the sun, where $R_B(t_B)$ is the radial distance of the comet at time t_B. This element continues to move radially outward and arrives at 1 AU (point D) with speed V_E at time $t_D = t_B + (R_E - R_B)/\bar{V}$ where $R_E = 1$ AU and $\bar{V}$ is the average solar wind speed between R_E and R_B. Since the solar-wind speed does not change appreciably between 0.4 AU and 1 AU (Parker 1963, p. 75), $\bar{V} \approx V_E \equiv V$. From the assumption of corotation, it follows that an element with the same speed $V_E = V$ passed the earth at time $t_E = t_D - \theta(t_E)/\omega_S$ where ω_S is the angular speed of the sun and $\theta(t_E)$ is the angle between the earth-sun line and the line of nodes at time t_E. Thus,

$$t_B = t_E - \left[R_E(t_E) - R_B(t_B)\right]/V + \theta(t_E)/\omega_S \tag{1}$$

Since the line of nodes of the comet was at 44° with respect to the earth-sun line on March 21 (day 80) (Figure 1b),

$$\theta(t_E) \approx 44^\circ - \omega_E\,(t_E(\text{days}) - 80), \tag{2}$$

where ω_E is the angular speed of the earth in its orbit about the sun, which we take to be circular.

B

During the period of interest (day 82-day 95), the radial distance between the sun and the comet changed only $\approx$25%, so to good approximation we may set $R_B(t_B) \approx a\ t_B + b$. From Figure 1, we obtain

$$R_B(t_B) \approx .007\ t_B - .028. \qquad (3)$$

The error in R_B resulting from this approximation is less than 1%.

Putting (2) and (3) into (1) gives the desired result

$$t_B = \frac{1}{1-(\frac{12.15}{V})}\left[.925\ t_E - \frac{1784}{V} + 9.4\right], \qquad (4)$$

where t_B and t_E are measured in days (Jan 1=1) and V is in km/sec.

Now it is a simple matter to transfer the observations at earth (Figure 3a) to the comet. One simply plots the quantities measured at earth at time t_E at a new time t_B. This gives Figure 3b, which shows the solar wind speed V and momentum flux nV^2 at the position of Comet Bennett as a function of time.

Recall that the kink was observed at Comet Bennett at 0258 UT on April 4. This is in the middle of the data gap. Nevertheless, for the reasons given earlier, there was very probably no fast stream at this time, and the actual speeds on days 92 and 93 are probably represented well by the straight line in Figure 3b. Thus, if our assumptions of corotation and $V(\lambda)$ = constant are valid, we must conclude that the kink was probably <u>not</u> caused by a change of solar-wind speed or momentum flux on a large spatial scale.

Let us now review the assumptions on which the above result is based.

Consider first the assumption of corotation. Pioneer 8 was essentially following the earth at this time, lagging the earth by an earth-sun-Pioneer 8 angle equal to $\approx 45^{\circ}$. If the solar wind were corotating, Pioneer 8 should have observed the same time profile as the spacecraft at earth, but 3 days earlier. Complete data from Pioneer 8 are not available; preliminary measurements give the result shown by the dashed curve in Figure 3b. This curve has been shifted by three days so that it should coincide with the heavy solid curve if the solar wind were corotating. Clearly, the solar wind was not steady. However, the stream on March 31 passed both OGO-5 and Pioneer 8 suggesting that it was essentially corotating, although there is evidence of some change with time. But Figure 3b shows that this stream did not hit the comet on April 4, if the other assumptions are correct.

Consider the assumption that $V(\lambda)$ = constant. If the stream cross-section were elliptical or circular, it should have arrived at the comet later than predicted in Figure 3b. A lag of 2.3 days is needed, but the maximum width of the stream is 1.8 days. Thus the stream which passed the earth on March 31 cannot be the cause of the kink in Figure 2 unless our assumption that ω_s = constant is a poor approximation. It is possible that the solar rotation period exceeds 27.5 days at $\lambda \approx 40^{\circ}$, and it might even be as long as 29.5 days (e.g. Wilcox, 1972), but this does not produce a sufficiently large change to shift the stream from March 31 to April 4. Furthermore, there is no stream at earth on April 2-4 which might be shifted by this effect such that it would meet the comet on April 4.

We conclude that there was no stream passing the earth in the interval March 30 to April 4 which could have caused the kink seen in the tail of Comet Bennett on April 4. This implies that either the solar wind structure differed greatly between the positions of Comet Bennett and earth (most probably due to the high latitude of Comet Bennett) or that the kink was caused by something other than a change in the solar wind.

There is other evidence which favors the hypothesis that the kink was caused by something other than large-scale changes in the solar wind. This is shown in Figure 2, where close inspection reveals at least three long, narrow, completely undisturbed rays right next to the kink. Such an arrangement of disturbed and undisturbed rays is inconsistent with a model which attributes the kink to a large-scale disturbance. We cannot, however, exclude the possibility that the disturbed rays were due to a small (order of 10^4 km), dense plug of solar wind material, such as that observed by Burlaga and Ogilvie, (1969).

Shock on April 1. Since this shock was not observed directly, nothing specific is known about it. It is fairly certain, however, that the speed was betweeen 300 km/sec and 700 km/sec, since 90% of the interplanetary shocks have speeds in this range (Hundhausen, 1972; Chao and Lepping, 1972). The most probable shock direction is radial, away from the sun, although there is a large scatter ($\approx 30^{\circ}$) in the direction of the shock normals (e.g. Chao and Lepping, 1972) and occasionally the shock normal may deviate as much as 55° from the radial direction (Lepping and Chao, 1972). If we assume a nearly spherical shock front, we find that the shock should have reached Comet Bennett at some time on March 31. Photographs of Comet Bennett taken at 1916 UT and 2252 UT on March 31 at the Tokyo and the Alma-Ata Observatories, respectively, show no disturbance even though the momentum flux probably changed by at least a factor of two across the shock. This result, then, is consistent with the hypothesis that a large, abrupt change in momentum flux is not sufficient to cause a large kink in a comet tail.

March 27, 1970, Shock and Stream. If the shock speed were 380 km/sec as calculated earlier and if the shock were nearly spherical as is the most probable case, then we can calculate that the shock should have hit the comet at 0400 UT on March 25. The stream which was seen to follow the shock near earth should have intercepted the comet somewhat later than $\approx$0400UT on March 25 if it were moving radially. If the stream were corotating, it should have arrived at the comet on March 28 (Figure 3b). The Pioneer 8 data in Figure 3a, although very sketchy, suggest that the stream was not corotating. In any case, these results indicate that a large change in momentum flux should have occurred at the comet between March 25 and March 28. Photographs taken at the Perth Observatory in Australia during the period March 25 to 27 and at Goddard Space Flight Center on March 28 show no evidence of a kink or any other such disturbance. These results suggest again that a large, abrupt change in momentum flux is not sufficient to produce an observable kink in a comet tail.

V. Summary

We have attempted to obtain a comprehensive picture of the solar wind and Comet Bennett in the period March 23 to April 5, 1970 when the comet was relatively close (≈ 0.7 AU) to the earth. Plasma data from four spacecraft and photographs from several observatories were analyzed. No evidence was found at the earth for a high speed stream or shock which could have caused the kink observed in the ion tail of Comet Bennett on April 4. Thus, either there was little correlation between measurements at the earth and at Comet Bennett, which was 40° above the ecliptic, or the kink in the ion tail was caused by something other than a high-speed stream. A photograph which shows undisturbed streamers superimposed on the kink favors the second of these alternatives.

There is geomagnetic evidence for a shock at earth at 2153 UT on April 1, which should have hit Comet Bennett between 0020 UT and 2240 UT on March 31 but there is no evidence of any effect of the shock in photographs of Comet Bennett at 1916 UT and 2252 UT. The solar wind observations indicate that a shock and a stream associated with a very large change in momentum flux should have hit Comet Bennett sometime between 25 March and 28 March. Photographs for this period show no evidence of a kink or other such disturbance. These results suggest that a large change in momentum flux of the solar wind is not sufficient to cause a large perturbation in a comet tail.

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Figure Captions

Figure 1a The trajectory of Comet Bennett in the orbital plane, which is essentially perpendicular to the ecliptic plane; here $\underset{\sim}{\hat{Z}}$ is normal to the ecliptic and $\underset{\sim}{\hat{Y}}$ is in the ecliptic plane.

Figure 1b Positions of the earth and Pioneer 8. $\underset{\sim}{\hat{X}}$ and $\underset{\sim}{\hat{Y}}$ are in the ecliptic plane, $\underset{\sim}{\hat{Y}}$ being the intersection of the comet's orbital plane with the ecliptic plane and $\underset{\sim}{\hat{X}}$ being normal to $\underset{\sim}{\hat{Y}}$. The projection of Comet Bennett's orbit in the ecliptic plane in the interval indicated on the Y axis; this can be seen more precisely in Figure 1a.

Figure 2 Comet Bennett 1970 (1969i) showing the dust tail and a pronounced kink in the ion tail. Notice the undisturbed rays right next to the kink (Photograph taken April 4, 0259 UT, by K. Lubeck, Hamburg Observatory, with 80/120/240 cm Schmidt telescope on Kodak 103a-O, exposure time 2 minutes).

Figure 3a The solar wind speed V and specific momentum flux nV^2 as measured at earth, and the speeds which would have been measured if the wind seen by Pioneer 8 were strictly corotating. The momentum flux is given by the triangles and the corresponding ordinate is on the right. All of the other points give speeds which are to be read from the ordinate on the left.

Figure 3b Solar wind speeds which the Comet would have enountered if the solar wind observed at earth corotated and if the solar wind speed were independent of solar latitude.

Figure 4 The geometry used in the model relating the solar wind at earth to that a Comet Bennett (see text). The diagram is clearly not to scale.

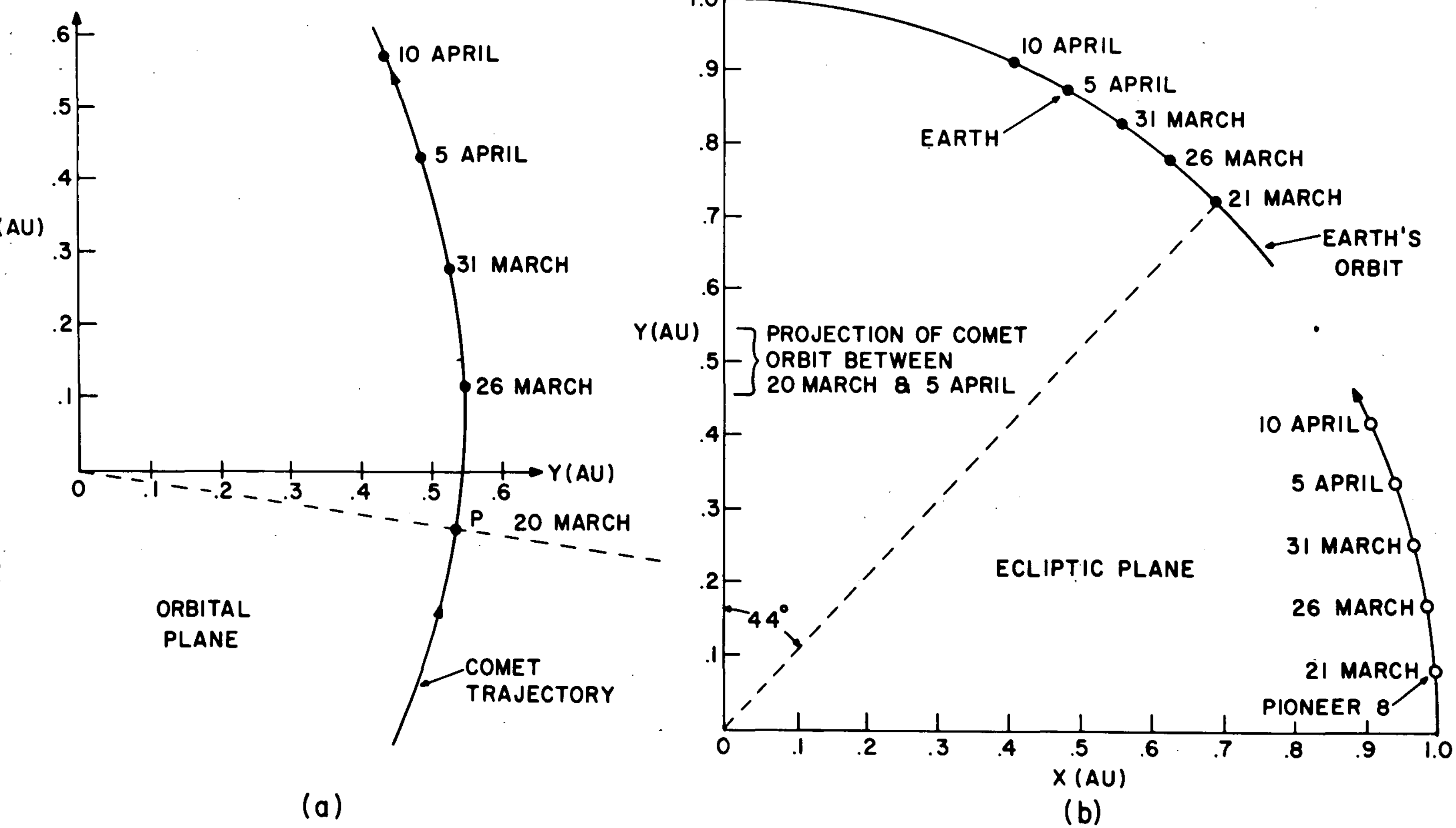
Z (AU)
.6
.5
.4
.3
.2
.1
0
.1
.2
.3
.4
.5
.6
Y (AU)
10 APRIL
5 APRIL
31 MARCH
26 MARCH
P
20 MARCH
ORBITAL PLANE
COMET TRAJECTORY
(a)
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Y (AU)
X (AU)
10 APRIL
5 APRIL
31 MARCH
26 MARCH
21 MARCH
EARTH
EARTH'S ORBIT
PROJECTION OF COMET ORBIT BETWEEN 20 MARCH & 5 APRIL
44°
ECLIPTIC PLANE
10 APRIL
5 APRIL
31 MARCH
26 MARCH
21 MARCH
PIONEER 8
(b)

FIGURE 1

Fig. 2

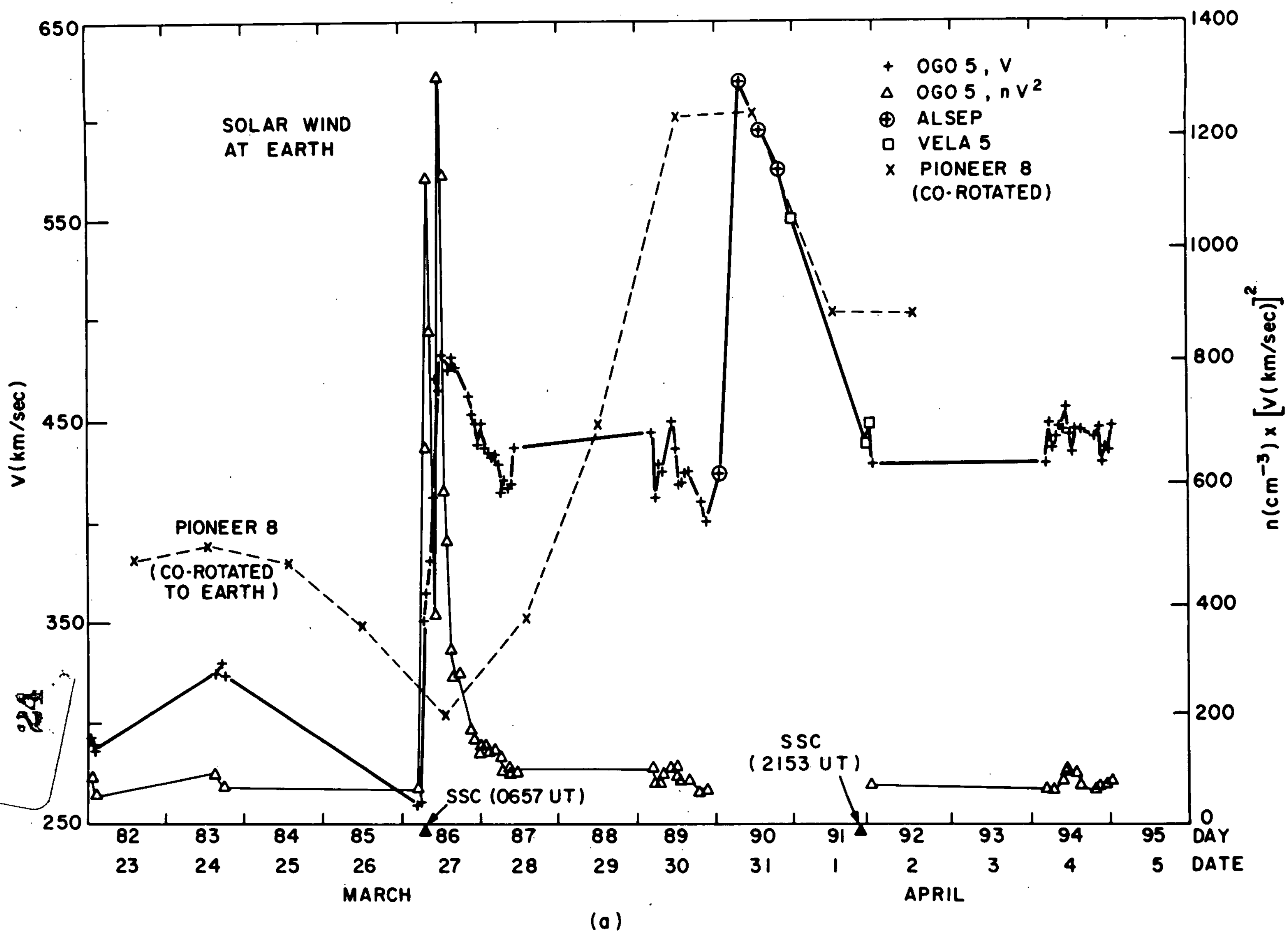
V(km/sec)
650
550
450
350
250
1400
1200
1000
800
600
400
200
0
n(cm^-3) x [V(km/sec)]^2
SOLAR WIND
AT EARTH
PIONEER 8
(CO-ROTATED
TO EARTH)
+ OGO 5, V
Δ OGO 5, nV^2
⊕ ALSEP
□ VELA 5
x PIONEER 8
(CO-ROTATED)
SSC (0657 UT)
SSC
(2153 UT)
82 83 84 85 86 87 88 89 90 91 92 93 94 95 DAY
23 24 25 26 27 28 29 30 31 1 2 3 4 5 DATE
MARCH
APRIL
(a)

FIGURE 3a

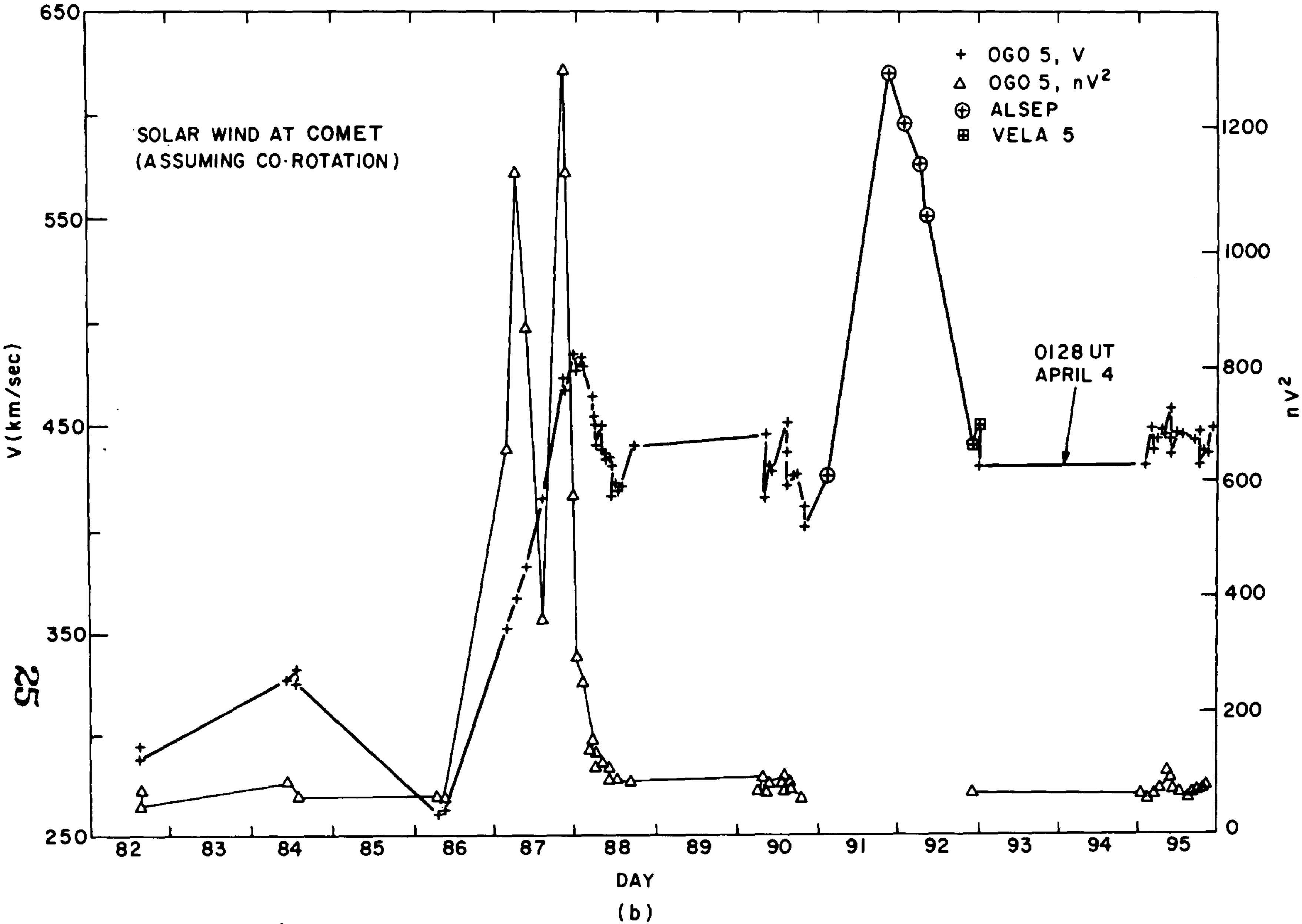
SOLAR WIND AT COMET
(ASSUMING CO-ROTATION)
OGO 5, V
OGO 5, nV²
ALSEP
VELA 5
0128 UT
APRIL 4
V (km/sec)
nV²
650
550
450
350
250
1200
1000
800
600
400
200
0
82
83
84
85
86
87
88
89
90
91
92
93
94
95
DAY
(b)

FIGURE 3b

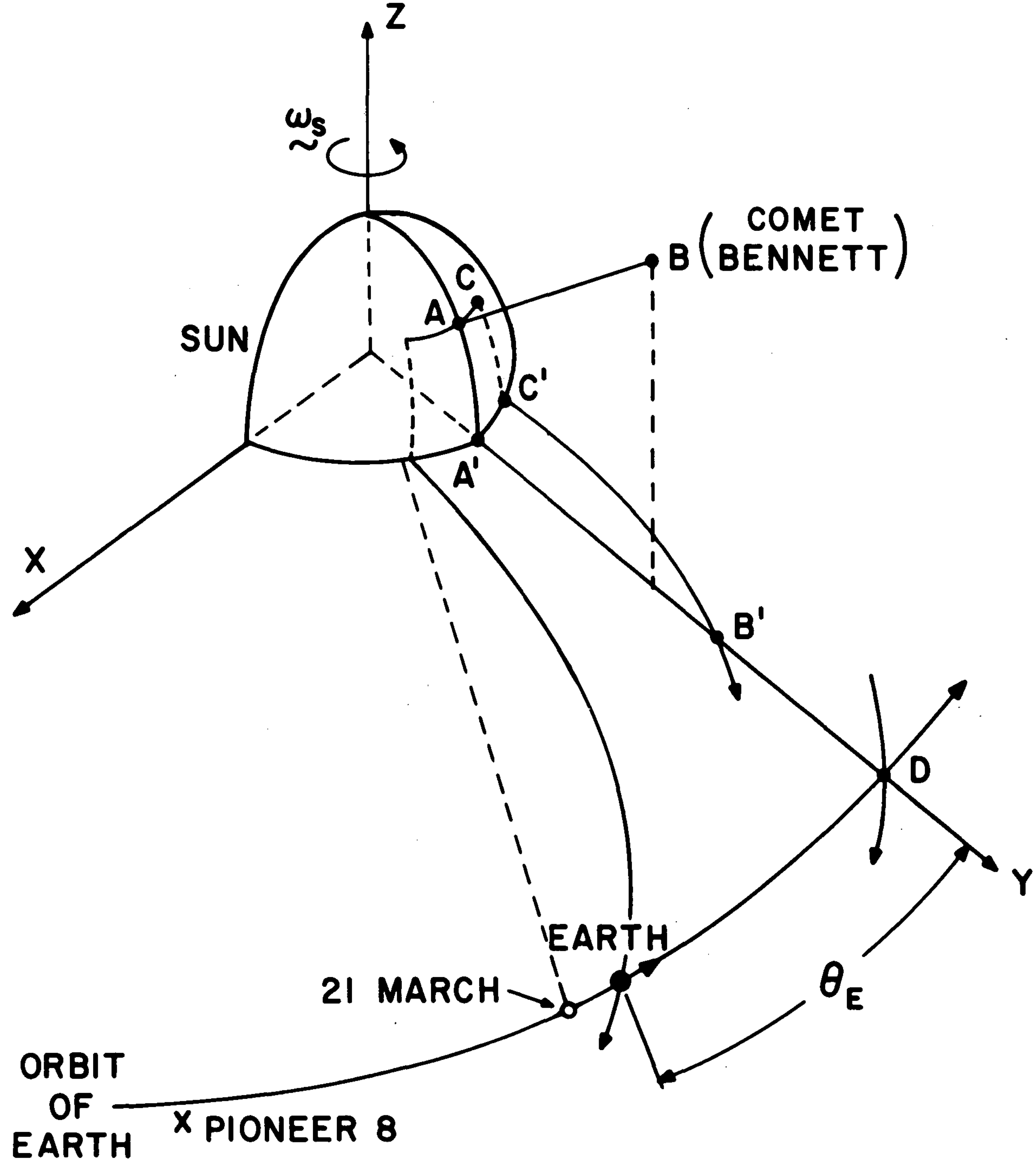

FIGURE 4

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